POINT TO POINT

TELECOMMUNICATIONS

A JOURNAL FOR THE TELECOMMUNICATIONS ENGINEER

VOLUME TWO · NUMBER THREE · JUNE 1958

Two shillings and sixpence

POINT TO POINT

TELECOMMUNICATIONS

Volume Two Number Three June 1958

Editor: A. J. Wheeldon, M.A, A.M.I.E.E

Points of View 2

Telegraph Receiver Design and its Influence on Testing
J. W. Clater, B.Sc(Eng.), A.M.I.E.E, and B. Ager, A.M.I.E.E 5

Simplification in Communications
R. B. Armstrong, B.Sc, M.I.E.E 19

The Analysis of Field Strength Records for Radio Link Assessment M. W. Gough, M.A, A.M.I.E.E 27

Editorial Board
A. W. Cole, A.M.I.E.E, C. Gillam, R. J. Kemp,
B. N. MacLarty, O.B.E, M.I.E.E

Published by the Communications Division

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ENGLAND

Points of view

RADIO SURVEYS as they are now understood are a comparatively recent innovation stemming from the exploitation of the frequency spectrum above 30 Mc/s and its utilization for point-to-point multi-channel radio links.

In the early days the purpose of the survey was two-fold. Firstly, it was necessary to establish the propagation characteristics at the frequencies being used, and based on these measurements, suitable sites for repeater stations had to be selected. These had to be confirmed by radio measurements which were sometimes quite lengthy. Secondly, full site data had to be prepared in such a form that it could be used as a basis for subsequent system planning and installation work.

At present, actual radio measurements for multi-channel systems operating in the VHF band are becoming more and more cursory since the factors governing propagation at these frequencies are now well known and performance can be predicted with fair accuracy. As a result it is sometimes considered that comprehensive surveys are no longer necessary for the simpler multichannel schemes. This attitude of mind stems from an incorrect appreciation of the factors which are taken into account during a survey. Even in the absence of radio measurements a survey brings about handsome economic dividends in that judicious choice of sites can influence the actual cost of an over-all project to quite a substantial extent. The cost of access roads and buildings is such that fairly substantial expenditure on a detailed study of a radio route on the ground is justified prior to the final specification of equipment and ancillary plant and the start of installation. The cost of a comprehensive survey of this kind is in fact modest when considered as a proportion of the installed cost of the complete project, and a provision of from 3% to 5%, depending on the physical problems, is usually quite adequate.

Economies of this order can frequently be made in planning the system when based on the detailed information which the survey provides.

Although propagation characteristics are now very much better known as a result of the substantial amount of information which has been collated over the past eight or ten years, the continual movement upwards into higher frequency bands, together with the steadily increasing channel capacity of the radio links which are now being contemplated, is demanding more, rather than less, information at the planning stage, and therefore adequate radio frequency measurements remain a factor of great importance in the final planning of a system. The possibility that there is a fundamental limit to the channel carrying capacity of a single radio system due to such factors as multipath is now becoming apparent, although it is not considered at the moment likely to have any limiting effect on the application of radio to multichannel systems. 600 or more channels can be carried on a single radio system, and where capacities higher than this are required multiple radio systems are used. This is an entirely practical proposition from the economic point of view, since the cost of carrier equipment almost invariably outweighs the cost of radio by a considerable amount and is in fact the most expensive single factor in a project of this size, unless the system operates over very considerable distances without channel access at intermediate points.

While it is true that no amount of experience can entirely eliminate the need for a survey in a given area for other than the simpler systems, the fact remains that an adequate collation of the results of past surveys enables very much more accurate predictions of performance to be made at the outset, and as a result lessens the duration and magnitude of the survey effort required to confirm the actual system requirement in terms of equipment. The existence of an adequate propagation research unit is therefore an asset of considerable value both to a manufacturer, and in turn to his potential customers.

It is frequently considered that surveys are only necessary for complex multichannel or television link projects. They can however be of very considerable value even when the establishment of conventional HF networks are contemplated. Factors such as site noise and level of

interference can have a profound effect upon the services obtained from a receiving station, and cases have not infrequently been observed where very expensive palliatives have been employed in order to render serviceable, even to a limited degree, a site which has become almost useless because of high noise level.

The same considerations apply to the establishment of scatter systems. The choice of sites in these instances are quite as important as in the case of high capacity multichannel links. Indeed, in some circumstances the choice can be more critical since the restrictions upon the foreground terrain in the neighbourhood of a scatter circuit are quite severe. Since the power consumption by such stations is considerable, problems of access and running cost assume great importance. These factors can be allowed for by undertaking adequate surveys at the outset, thus eliminating costly delays in the implementation of the final system.

Telegraph Receiver Design and its Influence on Testing

J. W. CLATER, B.Sc(Eng.), A.M.I.E.E, and B. AGER, A.M.I.E.E

The factors which affect the performance of high grade diversity telegraph receivers are discussed with particular reference to the problems which arise in testing. Some indications are given as to the causes for the falling off of performance that will occur with time.

1 INTRODUCTION

ALTHOUGH THE BASIC REQUIREMENTS of a receiving system have not changed for some years, the specific performance of modern equipment, and the methods of obtaining and checking that performance have made great advances, conditioned chiefly by the need to make the most effective use of the available frequency spectrum. In this article the more important aspects of the design will be briefly examined from a testing viewpoint and requirements for test equipment of the various types will be dealt with.

The type of receiver under discussion provides for the diversity reception of CW or MCW ON/OFF keying or FSK and is illustrated in Fig.1. The schematic diagram (Fig.2) shows a triple frequency-change superheterodyne receiver covering the signal frequency range of 3 — 27·5 Mc/s and using first, second and third intermediate frequencies of 2 600, 100 and 10 kc/s respectively. The adjacent channel selectivity of the receiver is determined by the selectivity of the second intermediate frequency amplifier, which is governed by the passband of the filters used. Typical passbands are 2 kc/s, 1, 0·5 kc/s or 0·25 kc/s.

A performance specification of a typical equipment is given in Appendix I.

Equipment	*Signal Freq. & IF1*	*Oscillator*	*IF2*	*AFC AGC*	*Det Recorder*	*Output*	*Unstab. P. Supply*	*Stab. P. Supply*	*Overall*
Signal Gen. Marconi Instruments Type TF.867	★								★
Valve volt Marconi Instruments Type TF.428C	★	★							
Valve volt Furzehill 378 B/2	★	★	★	★	★		★	★	
2.6 Mc/s reference oscillator	★								
Monitor receiver	★	★							
Output meter Marconi Instruments type TF.893	★	★							
Freq. standard Furzehill 1744	★	★							
Avometer Model 8	★	★	★	★	★	★	★	★	★
Battery potentiometer ± 2 v. D.C.		★							
Beat freq. osc. Marconi Instruments Type TF195M		★		★					★
*100 kc/s high discrimination osc. Marconi Instruments Type TF1168			★	★	★				
*10 kc/s high discrimination osc.				★	★				
H.R. centre zero voltmeter				★	★				
Path selector test unit W.26511					★				
*Telegraph Test Generator Marconi Instruments Type TF1167					★				★
Distortion counter									★
D.C. oscilloscope Furzehill 1684 N.					★				★
Loads							★	★	
75 ohm RF attenuator									★
Undulator Type UG6									★
Variac	★	★	★	★	★	★	★	★	★
Freq. measuring equipment Marconi Instruments Type TME2		★							
CRO Cossor Type 1035									★
Temperature Chamber	★								

Table 1. Equipment required to test Marconi HRII Receiver

2 TEST EQUIPMENT

Before considering the theoretical and practical details of some of the aspects of testing mention must be made of the test equipment required. Table 1 lists the essential items and their application to the various stages of the work on a typical receiver. Items marked with an asterisk have been specially developed to satisfy testing requirements where adequate test gear was not available.

The High Discrimination Oscillator is basically a very stable LC oscillator with four variable capacitors, three of which are frequency calibrated, and the fourth used for centre frequency adjustment against an internal crystal controlled oscillator. Carrier level is monitored, and 90 dB variable attenuation is provided. This instrument is used at centre frequencies of 100 kc/s and 10 kc/s for checking AFC and signal discriminator circuits, and the measurement of IF response where crystal filters are used in the equipment under test.

Most of the items mentioned in the table are self descriptive; certain of the more unusual ones justify special mention. Those items most

Second IF alignment using the high discrimination oscillator

Fig.1. Marconi double diversity telegraph receivers undergoing test

frequently used together are assembled in a Telegraph Test Rack which comprises a telegraph test generator, two audio oscillators, a DC telegraph output unit and a distortion counter unit together with power supply panels. It provides a keyed signal (ON/OFF, FSK or FSK Diplex) at frequencies of 10 kc/s, 50 kc/s and 100 kc/s, and also at 3·1 Mc/s, 6·2 Mc/s and 9·3 Mc/s. The equipment also accepts the telegraph output from the receiver under test and counts, over a predetermined period, the output pulses which have errors in length exceeding a given percentage (the usual test signal for this measurement is one of continuous reversals at a speed of 100 bauds). The percentage distortion reference level may be varied from 5% to 30% in steps, although the accepted figure at which measurement is carried out is for a distortion length in excess of 15%.

The Telegraph Distortion Counter, an electro-mechanical device, has a counting time of 10 mins. using the internal clock mechanism, but this time may be extended by the use of an external clock. Its counting capability is 8×10^6 element errors.

3 DESIGN AND TESTING CONSIDERATIONS

It will be appreciated that the tests necessary to ensure complete adherence to the performance specification are many and varied and only the more important aspects can be discussed. These include noise factor, sensitivity, selectivity and path selection.

3.1 NOISE FACTOR

The limit of a receiver's ability to handle weak signals is not set by its gain alone, since the noise introduced by the input circuit and first valve will appear in the receiver output as well as the signal.

The noise factor is a measure of the degree to which the receiver approaches the ideal (i.e. one possessing no internal noise sources). It can be defined as that factor by which the noise output, measured ahead of any non-linear element (such as the second detector), when connected to an aerial or its equivalent resistance at room temperature, exceeds that of an ideal receiver, having no internal noise sources but possessing the same gain and bandwidth properties when connected to the same aerial.

In order to achieve a good noise factor the input ratio (that is the ratio of the receiver input to the input at the valve grid of the first signal frequency stage) must be as high as possible. This ensures that the aerial noise component at the valve input connection is at a maximum compared with the shot noise of the valve (normally a low noise type having an equivalent noise resistance of about 2 000 ohms). The noise factor of the receiver is normally governed by the characteristics of the first SF stage, as the noise introduced by the second stage will be negligible (since its equivalent noise resistance is divided by the square of the stage gain). However, the requirement that the frequency-changer must have a negligible effect upon the noise factor is more difficult to achieve, since the equivalent noise resistance is inherently very high (about 200 000 ohms). Thus, if the gain of the two SF stages is only 20 dB, the frequency-changer noise referred to the grid of the first valve is 2 000 ohms which is equal to that of the first SF valve and the overall noise factor will, therefore, be degraded. In a well designed receiver the gain of the SF stages should, therefore, exceed about 26 dB.

The noise factor is measured by connecting a noise generator to the aerial input socket and a millivoltmeter to the output of the 100 kc/s amplifier and then increasing the noise generator output from zero to such a level that a 3 dB rise is indicated on the millivoltmeter. The noise factor may then be read directly from the instrument (on modern test equipment) or on noise generators reading DC diode current only, by applying the formula:

$N = 20\, I_{DC} R$ where
I_{DC} = noise diode current (amps)
R = noise generator shunt resistance

Assuming correct design, a high noise factor may be due to:

(a) Low mutual conductance of the SF valves.
(b) High resistance contacts on the SF circuit switches.
(c) Low 'Q' SF inductances.
(d) Insufficient oscillator voltage at the frequency-changer valve (causing low conversion gain).
(e) Mis-alignment of the SF circuits.

In service the gain of the receiver will fall with time due to one or more of the above causes and Fig.3 shows the relationship between gain and noise factor in a particular receiver; it will be seen that the noise factor starts to rise when the gain has fallen by approximately 5 dB.

3.2 DEMODULATOR PERFORMANCE

Whilst the noise factor indicates the signal-to-noise ratio that can be expected from a given input signal and IF bandwidth, this is not the only consideration in dealing with telegraphy reception. Here the primary interest is the error rate of the printed message, and the relationship between signal-to-noise ratio and error rate needs to be evaluated.

Since various telegraph printing systems will withstand different amounts of telegraph distortion before errors are printed, an arbitrary distortion figure must be chosen for measuring purposes and a figure of 15% is usual. Hence to take this measurement, 100 baud FSK reversals with a shift of 560 c/s are obtained from a telegraph test generator and fed to the receiver input at a frequency which is usually 3·1 Mc/s. The input signal is reduced until an average error rate of 1 per 1 000 elements having a distortion in element length exceeding 15% is registered on a short element fault counter connected to the DC output of the receiver. For this signal the corresponding IF signal-to-noise ratio is measured with a millivoltmeter. As an alternative, a telegraph distortion measuring equipment could be used. For a 50-baud system the telegraph test generator can be keyed from a 5-unit sending head fed with a test message on tape and a standard printer used for recording, the copy being analysed for errors.

If a poor demodulator performance is obtained it may usually be ascribed to poor signal discriminator alignment or malfunctioning of the signal shaping and low pass filter circuits.

3.3 INPUT SENSITIVITY

Having measured the noise factor and the demodulator performance, the necessary receiver input voltage can be calculated, as in the following example:

Noise Factor = 7 dB

Demodulator Performance = 10 dB S/N ratio

(for 560 c/s shift 1 kc/s bandwidth)

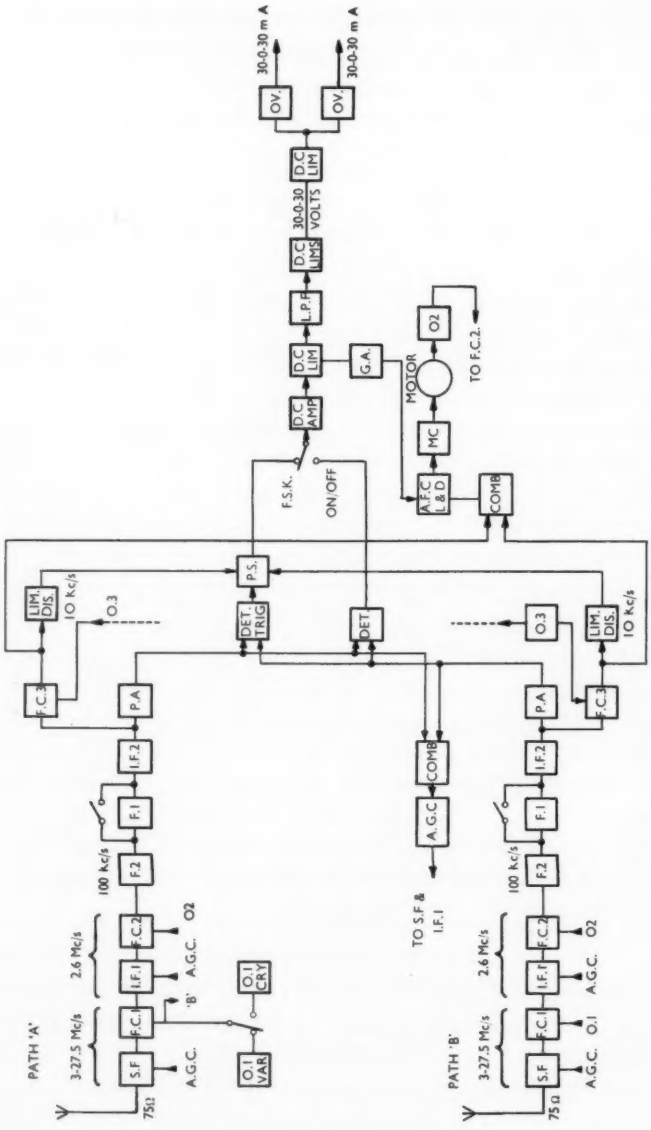


Fig.2. Schematic diagram of typical double diversity telegraph receiver

KEY TO FIG.2

S.F	Signal frequency amplifier	A.G.C	Automatic gain control amplifier
F.C	Frequency changer (1st 2nd and 3rd)	D.C Amp	D.C Amplifier
		D.C LIM	D.C Limiter
I.F	Intermediate frequency amplifier (1st and 2nd)	L.P.F	Low pass filter
		O.V	D.C Output valves
F1	100kc/s crystal filter 1kc/s BW or 0·5kc/s BW	G.A	A.F.C Gate amplifier
		A.F.C L & D	A.F.C Limiter and discriminator
F2	100kc/s crystal filter 2kc/s BW or 1kc/s BW	M.C	A.F.C Motor control circuits
		O.1 VAR	First oscillator (variable)
P.A	100kc/s power amplifier	O.1 CRY	First oscillator (crystal)
P.S	Path selector	O.2	Second oscillator
		O.3	Third oscillator (90kc/s)
LIM.DIS	Signal limiter and discriminator (10kc/s)	DET & TRIG	Detector and trigger circuits
		COMB	A.F.C and A.G.C Combining circuits
DET	ON/OFF detector and slide back		

Since it can be shown that with an input voltage of 1 μV, an ideal receiver gives a signal-to-noise ratio of 29 dB (for 1 kc/s bandwidth), the input required on the above receiver is:

$$-29+7+10=-12\ \text{dB}/\mu\text{V}$$

This method can, of course, be used with other bandwidths and shifts, and for ON/OFF keying.

3.4 SELECTIVITY AND BANDWIDTH

In order to achieve a high standard of performance, modern telegraph receivers employ crystal filters to determine the selectivity. In a typical case, each filter consists of 2 identical sections connected in tandem, each section consisting of a bridged-T network, the series element formed by a crystal and inductor in parallel and the shunt element by a resistor.

The filter must offer sufficient rejection to an adjacent signal and the minimum distortion to the wanted signal. The latter requirement dictates that the pulse response must have minimum overshoot. There is an

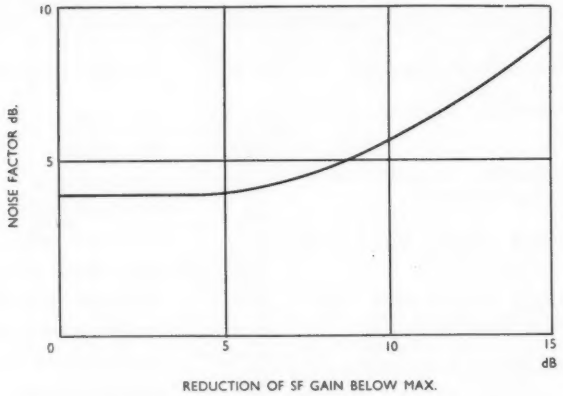


Fig.3. Reduction in noise factor with loss of receiver gain

optimum shape of cut-off which is the best compromise between these conflicting requirements, which can be specified approximately by:

Bandwidth at − 3 dB = 630 c/s
Bandwidth at − 6 dB = 900 c/s
Bandwidth at − 70 dB = 2 700 c/s
For a filter having 1 kc/s nominal bandwidth.

A note on bandwidth requirements for various keying speeds is given in Appendix II.

Factory testing of the filter not only ensures that response and insertion losses are correct, but aims at ensuring a permanence of these characteristics by the testing methods used. For example, all inductors are heat cycled, the filters are dried under vacuum conditions and alignment, which should ideally be carried out in a vacuum, is carried out with nitrogen flowing through the filter. This prevents the ingress of air and moisture whilst adjustments are in progress.

Since the filters are designed to work between high impedance points it is not easy to test them in isolation. *In situ* tests can be satisfactorily achieved by using the High Discrimination Oscillator.

3.5 DIVERSITY PATH SELECTION

In the case of ON/OFF keying the detection is normally carried out by diodes which are fed from linear IF amplifiers. Here diversity path combining is achieved simply by adding the detected signals together in a linear or square law circuit. Although the AGC is fully operative, signal levels will be varying with the fading but the noise levels will be constant. Conversely, for FSK reception with limiters and discriminators, the signal in each diversity path has been limited before it is fed to the discriminator. The output signals from the discriminators will be the same for each path irrespective of the signal amplitude before limiting, but the noise components will vary with the signal amplitude. If we add the two (or three) discriminator outputs together the path with the poor signal-to-noise ratio will degrade the better paths.

One solution is to compare the signal amplitudes before limiting. The comparator circuit operates a trigger circuit which in turn controls the discriminator outputs. The gate controlling the path with the strongest signal is open; the others are shut.

Let b = the 'backlash' of the trigger valve
S_A = the signal amplitude in path A
S_B = the signal amplitude in path B
G = gain of the amplifier preceding the comparator.

The difference between the signals in the comparator must be equal to the trigger backlash when switching takes place, so

$$b = G\,(S_A - S_B)$$

Thus we see that the larger the signal amplitude the smaller the difference (expressed in decibels) required to switch.

This can be verified by connecting a signal generator via two (or three) separate attenuators to the 100 kc/s IF amplifiers. The attenuators are set to give the desired level and then one of them is slowly altered until switching takes place. This can be observed by noting the path selector trigger feed. If the results are plotted for different signal levels they will be similar to those shown in Fig.4.

In service, double diversity path selectors should need little maintenance, but triple diversity selectors will need more attention since the

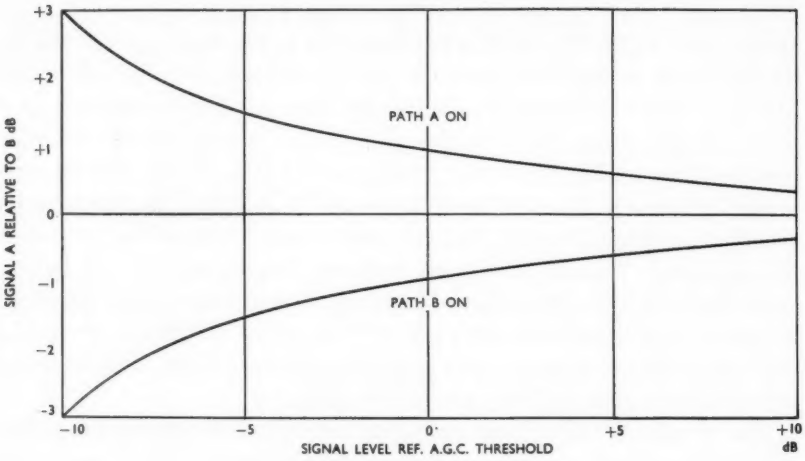


Fig.4. Path selector characteristics

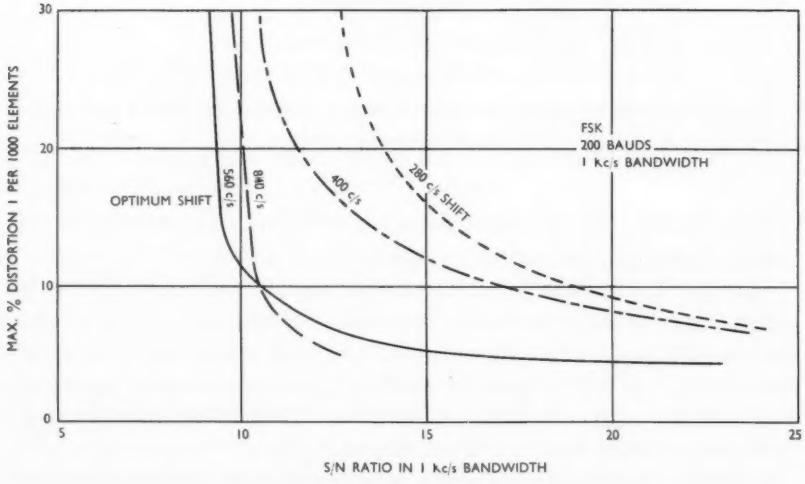


Fig.5. Relationship between frequency shift and demodulator sensitivity

comparator and trigger circuits are relatively complicated. In such cases the use of a Path Selector Test Unit greatly simplifies testing and setting up. The unit consists of three continuously variable attenuators which feed the three diversity paths, the input to the unit being obtained from a signal generator at 100 kc/s.

CONCLUSIONS

This survey will have indicated, to some extent, the scope of the tests and test equipment necessary for this class of work. It should be noted that the advent of printed circuitry and the use of transistors have already stimulated ideas and development work on automatic testing techniques but it is not anticipated that the test equipment listed in Table I will be outmoded for some time to come.

Appendix I

ABRIDGED SPECIFICATION SUMMARY FOR TYPICAL DOUBLE DIVERSITY TELEGRAPH RECEIVER

Types of signal received:
Double diversity reception of CW or MCW ON/OFF keying, or FSK (100–840 c/s shift)

Frequency Range:
3–27·5 Mc/s in four bands

Input: 75 ohm coaxial

Sensitivity:
0·25μV ± 2dB input required at 27·5 Mc/s with a 1 kc/s passband for FSK (560 c/s shift) giving 15% distortion (1 per 1000 characters) at 100 bauds. (0·35μV ± 2dB for ON/OFF Signals).

Noise Factor:
4dB at 3 Mc/s and 7dB at 27·5 Mc/s

Image signal protection:
120dB at 3 Mc/s and 63dB at 27·5 Mc/s

Selectivity (First IF):
11 kc/s wide at 3dB attenuation. 34 kc/s wide at 20dB attenuation

Selectivity (Second IF):
0·25 kc/s filter:
0·26 kc/s wide at 6dB attenuation. 0·93 kc/s wide at 60dB attenuation
0·5 kc/s filter:
0·4 kc/s wide at 6dB attenuation. 1·4 kc/s wide at 70dB attenuation
1 kc/s filter:
0·9 kc/s wide at 6dB attenuation. 3 kc/s wide at 70dB attenuation
2 kc/s filter:
2·2 kc/s wide at 6dB attenuation. 7 kc/s wide at 70dB attenuation

Frequency Stability:
Variable first oscillator 15 parts in 10^6 per °C. Crystal first oscillator 1 part in 10^6 per °C. Second oscillator 15 parts in 10^6 per °C

AFC:
Frequency drifts up to ±3 kc/s are followed with a residual error of less than 4 c/s

AGC:
20dB change in output for 80dB change in input

Max. Receiving speed:
300 bauds with 2 kc/s bandwidth at 840 c/s shift

Radiation of first oscillator measured at aerial terminal is less than 100μV at any frequency.

Power Supplies:
Requirements are 500 w at 200–250 v. 50 c/s. Single phase AC supply. Voltage variation ±6%. Frequency variation ±4%

Appendix II

The C.C.I.R recommend that in the case of ON/OFF signals on a deeply fading circuit the bandwidth should be five times the keying speed in bauds, e.g:

IF Bandwidth	2kc/s	1kc/s	0·5kc/s	0·25kc/s
Maximum in Bauds Speed	400	200	100	50

Where fading is not too rapid and some increase in bias distortion can be tolerated, the maximum speeds can be increased.

In the case of frequency shift signals, the C.C.I.R recommend that the following formula be used to calculate bandwidth for modulation indices between 2·5 and 8·0.

$$\text{Bandwidth} = 1{\cdot}25S + 0{\cdot}5B,$$

where M, the Modulation Index

$$= \frac{\text{frequency shift in c/s (S)}}{\text{keying speed in bauds (B)}}$$

In order to reduce effective noise and conserve channel space, bandwidth must be decreased to the minimum by the use of modulation indices below 2·5.

For Modulation Indices between 1 and 2·5,

$$\text{Bandwidth} \frown S + B$$

For any given keying speed and bandwidth there is a value of shift which gives the optimum demodulator performance. From Fig.5 it can be seen that for a bandwidth of 1kc/s and a keying speed of 200 bauds the optimum value of shift is 560c/s.

If similar curves are taken for other bandwidths it will be found that the optimum shifts are those given below.

Bandwidth	2kc/s	1kc/s	0·5kc/s	0·25kc/s
Keying in Bauds Speed	300	200	100	100
Optimum Shift	840c/s	560c/s	280c/s	140c/s

J. W. CLATER, born 1918 in Gibraltar. Educated at Plymouth. Later entered the British Post Office. He was with the Royal Engineers and later the Royal Signals throughout the last war, after which he studied Engineering at Bristol University.

He joined the Marconi Company in 1949 and is now in charge of the Sales Engineering Section of Communications Division responsible for HF and Scatter equipment, and the export of VHF mobile systems. He also serves on the Mobile Radio Committee set up by the Government to advise the Post Office.

B. AGER, born in 1914 at Galleywood, Essex. Educated at King Edward VI Grammar School and Mid-Essex Technical College.

Joined the Marconi Company in 1935 after service with Joseph Lucas Ltd. Has held various positions in the Test Division and is now in charge of Receiver Test Sections which cover a wide range of the Company's products including the International class receivers discussed in his article.

Simplification in Communications

R. B. ARMSTRONG, B.Sc, M.I.E.E

This article discusses the part that can be played in 'simplifying' telecommunications systems by the agreed reduction of an unnecessary variety of techniques.

1 INTRODUCTION

PERHAPS THE MOST fundamental example of simplification in communications is the adoption of national standards of speech. This illustrates in one example the advantages of standardization and the difficulty in its achievement in that mankind, while agreeing as to the desir ability, has not been able to get further than national standards of speech. The task is one of singular difficulty in that progress in simplification or standardization can only take place with the agreement of all concerned and therefore is confined to the relatively small amount of common ground that exists in any one field.

Simplification, by the selection of suitable standards, may be considered in relation to telecommunication activities under three distinct aspects: the materials, components etc. available to the design engineer; the codes of design and production practices which control the end products and finally the operational and system-planning codes of practice under which these end products function.

It is however particularly in the sphere of system-planning that the telecommunications engineer must think internationally to a greater degree than in most other branches of applied science, since in point-to-point telecommunication networks, equipment designed to a variety of standards must be capable of compatible operation.

2 SIMPLIFICATION IN RAW MATERIALS COMPONENT PARTS, ETC

It is perhaps not generally realized how recent has been the birth of any effective effort to establish standards on an industrial basis.

This activity originated in large degree in the United Kingdom but it

was not until the beginning of this century that a letter from a London merchant appeared in *The Times* suggesting the benefits that could be obtained through simplification by selective standardization of the weights and sizes of steel girders. This appears to have led shortly afterwards to the formation of the first British Engineering Standards Committee. It was as recently as 1931 that the British Standards Institution was established in its present form and accelerated the introduction of the current series of British Standard Specifications for optional use by industry.

These British Standard Specifications are often preceded by those prepared to meet sectional, rather than national, requirements. Trade associations and Government-sponsored organizations may provide their own internal standards pending the issue of a British Standards Specification.

International standards for industrial products have followed a similar but even slower pattern of growth. Thus the organization for the international standardization of general engineering products was not born until 1926 as the International Federation of National Standardization Associations. After the disruption caused by World War II this work was begun again under the United Nations Co-ordination Committee in 1944 and the present organization for international standards, the I.S.O, was not constituted until 1946.

International standardization in electrical engineering was an earlier conception. The International Electrotechnical Commission (I.E.C), of which Lord Kelvin was the first President, was constituted in 1905. Like the I.S.O it is now affiliated to the United Nations Organization and is playing an increasingly active part in crystallizing international conceptions of simplification through agreed standardization.

2.1 COMPANY STANDARD SPECIFICATIONS

It is impractical for any large manufacturing organization to use, for its daily design and production routine, standardization documents originating from a wide variety of sectional, national or international sources. It is therefore essential to make readily available for internal use highly condensed Company Standard Specifications which reflect the best

CABLE, PVC INSULATED, UNSCREENED, 2000 V DC.

CATALOGUE SHEET
PW.1214

STANDARD METHOD OF SPECIFYING: QUOTE TITLE, SIZE, DESCRIPTION AND COLOUR, FOLLOWED BY STANDARD IDENTITY. e.g. CABLE, 1/.024, INSUL., RED. PW.1214/1.

ISSUE 2
DATE 31.1.57

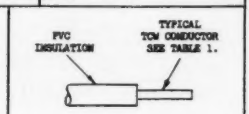
SUPPLIERS NOTES.

A. THESE CABLES SHALL BE SUPPLIED UNDER THE MARCONI IDENTITIES QUOTED AND IN ACCORDANCE WITH THE DATA GIVEN. THEY SHALL BE CAPABLE OF MEETING ALL THE TECHNICAL REQUIREMENTS OF DEFENCE SPECIFICATION DEF-12-A FOR TYPE 3 CABLES. CROSS REFERENCE TO JOINT SERVICE CATALOGUE NUMBERS IS GIVEN FOR CONVENIENCE.

B. COLOURS SHALL BE IN ACCORDANCE WITH BS.2746.

C. REELING. UNLESS OTHERWISE SPECIFIED THE CABLES SHALL BE SUPPLIED ON REELS IN LENGTHS OF 100 YARDS.

D. MARKING. THE LABEL ON EACH REEL SHALL BE CLEARLY MARKED WITH THE STANDARD IDENTITY. TYPICAL MARKING PW.1214/1.



STANDARDISATION NOTES.

1. APPLICATION.
TABLE 1 GIVES STANDARD SIZES AND COLOURS FOR GENERAL USE WITHIN THEIR RATINGS FOR INTERNAL WIRING OF MARCONI DESIGNS.

2. TECHNICAL DATA.

(a) INSULATION TEMPERATURE LIMITS.
-40°C AND +85°C.

(b) RATING.
(i) MAX. WORKING VOLTAGE:- 2000V DC. 1500V rms AT 50 c/s.

(ii) CURRENT RATINGS FOR A 20°C RISE ARE GIVEN IN TABLE 2.

(c) OTHER TECHNICAL DATA.
SEE TABLE 2.

● NOT NORMALLY STOCKED

TABLE 1

STANDARD COLOUR, SIZES & REFERENCE NUMBERS

SIZE	1/.024		1/.044		14/.0076		40/.0076		70/.0076	
COLOUR	J.S.CAT. No.6145-	REF. No.	J.S.CAT. No.6145-	REF. No.	J.S.CAT. No.6145-	REF. No.	J.S.CAT. No.6145-	REF. No.	J.S.CAT. No.6145-	REF. No.
RED	424094	1	424104	34	424.11	45 ●	100227	12	100231	23
BLUE	100215	2	424098	35	100221	46 ●	424125	13 ●	424132	24
GREEN	100216	3	424100	36	100222	47 ●	424126	14	424133	25
YELLOW	100217	4	424107	37	100223	48 ●	424130	15	424137	26
BLACK	100218	5	424097	38	100224	49	424124	16	424131	27
WHITE	100219	6	424106	39	100225	50 ●	100228	17	100232	28
BROWN	424091	7	424099	40	424108	51 ●	100229	18	100233	29
VIOLET	424095	8	424105	41	424112	52 ●	424129	19	424136	30 ●
ORANGE	424093	9	424102	42	424110	53 ●	424128	20	424135	31 ●
GREY	424092	10	424101	43	424109	54 ●	424127	21 ●	424134	32
PINK	100220	11	424103	44	100226	55	100230	22	100234	33

TABLE 2

CONDUCTOR SIZE	CONDUCTOR NOM. AREA SQ. IN.	RADIAL THICKNESS INSULATION IN.	OVERALL DIAMETER IN. MAX.	OVERALL DIAMETER IN. MIN.	CONTINUOUS CURRENT RATING AMP.	MAXIMUM RESISTANCE AT 20°C OHMS PER 100 FT.	WEIGHT APPROX. LB. PER 100 FT.
1/.024	.00045	.018	.064	.054	2	2.0	.321
1/.044	.0015	.018	.084	.074	6	.557	.787
14/.0076	.0006	.024	.084	.074	2.5	1.401	.514
40/.0076	.0017	.024	.107	.097	7	.490	1.091
70/.0076	.0031	.024	.129	.119	12	.280	1.710

ASSOCIATED SPECIFICATIONS.
BS.2746
DEF-12-A

SUPPLIERS

B.I. CALLENDER'S LTD.
J. DAY & CO. LTD.
DURATUBE & WIRE LTD.
W.T. GLOVER & CO. LTD.
W.T. HENLEY'S CO. LTD.
PERMAMOID LTD.
RELIANCE ELECT. CO. LTD.
RIST'S WIRES & CABLES LTD.
SIEMENS BROS. & CO. LTD.
WANDLESIDE CABLES LTD.

ISSUED BY MARCONI'S WIRELESS TELEGRAPH CO. LTD. CHELMSFORD ENGINEERING DEPT. STANDARDISATION DIVISION. COPYRIGHT RESERVED.

MS.5
MS.2

national or international practices available, but which do not hesitate to outstrip the latter when they are inadequate. In the particular case of the Marconi company, seven volumes of such Company Standard Specifications are maintained covering:

Components	Fasteners
Hardware and Sundries	Raw Materials
Cables and Wires	Processes

Quartz Crystals

Typical sheets covering one type of PVC-insulated hook-up wire and a Grade 1 PTFE valveholder are illustrated. It will be noted that they are based on the most stringent Ministry of Defence, Ministry of Supply or British Standard Specifications which are available, as this has been found to be the most straightforward way of ensuring designs which are satisfactory in the widely varying conditions experienced throughout the world.

2.2 SOME ADVANTAGES OF COMPANY STANDARDS

It is obvious that by selecting the best features available in national or international practices the highest standard of common practice will emerge ultimately—an objective which must be of paramount interest to both manufacturer and user.

On the economic side the benefits of longer production runs and the consequent spread of initial design and tooling costs are directly calculable and generally accepted. There is not so general an appreciation of the indirect economies achieved. A major item in this category is very often the time saved by highly paid design staff when provided with concise data from which to make their selection of standard materials or practices.

An even greater hidden economy may lie in the cross-reference which the Company Standard Specification can provide between the various identities by which the same component may be known by individual manufacturers or by Government-sponsored organizations. It will be noted that the valveholder specification illustrated gives reference to the British Joint-Service identity and the identities of the various manufacturers. The data quoted on the sheet in question is, in fact, crystallized from upwards of a dozen publications.

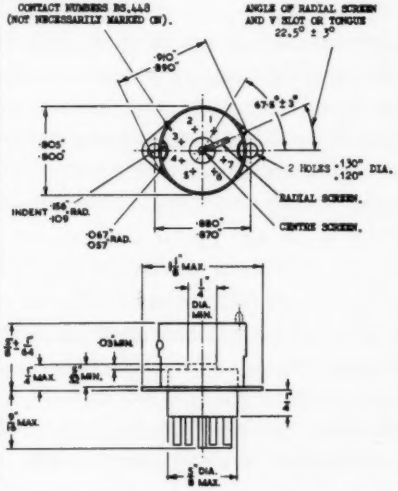
VALVEHOLDER, B7G, GRADE 1, WITH SKIRT.

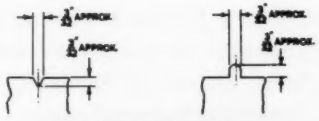
CATALOGUE SHEET
PC.81823

STANDARD METHOD OF SPECIFYING: QUOTE TITLE, DESCRIPTION AND STANDARD IDENTITY, e.g. VALVEHOLDER, B7G, GRADE 1, WITH SKIRT. PC.81823/1.

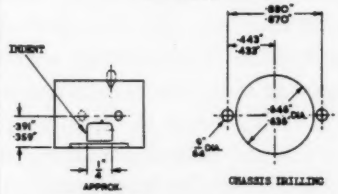
ISSUE 2
DATE 15.9.54

THIRD ANGLE PROJECTION.





DETAIL OF SLOT OR ALTERNATIVE TONGUE (SEE NOTE 4).



DETAIL OF SKIRT

CHASSIS DRILLING

SUPPLIERS NOTES.

A. THIS VALVEHOLDER SHALL BE SUPPLIED UNDER THE MARCONI IDENTITY QUOTED AND IN ACCORDANCE WITH THE DATA GIVEN. IT SHALL BE CAPABLE OF MEETING ALL THE TECHNICAL REQUIREMENTS OF BCS.251. CROSS REFERENCE TO THE JOINT SERVICE CATALOGUE NUMBER IS GIVEN FOR CONVENIENCE.

B. EACH VALVEHOLDER SHALL BE CLEARLY AND INDELIBLY MARKED THUS:- PC.81823/1.

STANDARDISATION NOTES.

1. APPLICATION.
GENERAL USE IN MARCONI DESIGNS WITHIN ITS CATEGORY RATINGS. THIS VALVEHOLDER IS COSTLY COMPARED WITH ITS GRADE 2 COUNTERPART. IT SHOULD NOT BE USED EXCEPT FOR THOSE CONDITIONS OF HUMIDITY OR FREQUENCY WHICH CANNOT POSSIBLY BE MET BY THE USE OF PC.81811/1.

2. TECHNICAL DATA.
(a) CLIMATIC CATEGORY.
SUITABLE FOR USE IN AMBIENT TEMPERATURES BETWEEN -40°C AND +100°C AND HUMIDITY CONDITIONS H1.
(b) RATING.
VOLTAGE - 750V DC WORKING.
(c) GRADING.
GRADE 1 VALVEHOLDERS HAVE AN EQUIVALENT RESISTANCE, MEASURED AT 20 Mc/s BETWEEN THE TWO CLOSEST CONTACTS, OF NOT LESS THAN 0.75 MEGOHM.
(d) MATERIAL AND FINISH.
BODY - P.T.F.E.
SKIRTED SADDLE - CADMIUM PLATED.
CONTACTS - SILVER PLATED.
TAGS - DIP-TINNED.

3. MOUNTING.
(a) VALVEHOLDER MUST BE MOUNTED ABOVE CHASSIS.
(b) RECOMMENDED FIXING SCREWS - 6BA CHEESE HEAD.

4. VALVE ORIENTATION.
AS ALTERNATIVE TO SLOT OR TONGUE THIS VALVEHOLDER MAY BE PROVIDED WITH SOME OTHER DEVICE IDENTIFIABLE BY TOUCH.

5. SCREENING CANS.
FOR SUITABLE CANS SEE SECTION 'C', CANS, VALVE SCREENING, B7G.

J.S. CAT. No.	REF.	
Z.560094	1	

ASSOCIATED SPECIFICATIONS. BCS.251. BS.448.

SUPPLIERS TYPE APPROVED.

HILLMAN (CLIX)	VR.337/701/CPS, VR.337/702/CPS, VR.337/703/CPS, VR.337/704/CPS.
McMURDO	FM7/SC.1.

ISSUED BY MARCONI'S WIRELESS TELEGRAPH CO. LTD. CHELMSFORD. ENGINEERING DEPT. STANDARDISATION DIVISION.

COPYRIGHT RESERVED

MS.31

3 SIMPLIFICATION IN DESIGN AND PRODUCTION CODES OF PRACTICE

Telecommunications equipments are products making use of the experience of the applied physicist, the mechanical designer and the production engineer.

There are few features of the equipment that do not involve all three of these interests; as an example, the specification by the mechanical designer of a supporting member in the output stage of a transmitter may be influenced by the power factor of the material to at least as great an extent as by its ultimate tensile strength; additionally, he must ensure that the material is suitable for the machining processes involved in its manufacture.

It is therefore often impossible to make a clear-cut distinction between design and production codes of practice. Nevertheless the circulation of data covering codes of practice selected by agreement falls naturally into four broad headings, Circuit, Mechanical, and Process Design Data, and Workshop Standard Practice.

In a field as dynamic and expanding as that of the telecommunications engineer, it is of course essential that circuit design data should be presented in a form which will serve as a springboard for improvement rather than as a bar to the introduction of new practices. Nevertheless it is noteworthy that the American Bureau of Standards has found it worthwhile to issue, on behalf of the Naval Bureau of Aeronautics, a handbook of a series of preferred circuits covering a wide range of requirements. The introductory sheets emphasize the importance of treating the publication as a means of reducing an unnecessary number of methods of achieving precisely the same required performance, rather than discouraging improved performances as the need for the latter arises.

Similarly, much is done in many large organizations to circulate mechanical design data which prevent uneconomic overlap in approaching common design problems.

Apart from the internal economy of effort thus possible, it is only through this routine that conformity to national or international practices may be achieved.

An outstanding example of the need for this philosophy is found in the various series of screw threads which form a serious handicap to the international exchange and subsequent maintenance of the simplest engineering product. Of the 57 different thread series which have grown up since the introduction of the Whitworth thread form in 1841, it would be difficult to justify the perpetuation of more than half a dozen on the score of essential technical requirements. The adoption of the unified thread form for threaded parts above ¼″ diameter, by American, British and Commonwealth agreement, is a valuable first step on a long road; since a 60° thread profile has been adopted which meets the essential requirement of the metric series of screws it may ultimately lead, through I.S.O, to agreement on world standards for the normal run of nuts and bolts.

Simplification of finishing process practices is another field in which adequate collaboration between the user of equipment on the one hand and the design and production engineering departments of the manufacturer on the other hand is essential in the interests of both. It is under this heading that the processes which condition the raw materials used in a product to the climatic requirements under which the equipment must operate, fall.

Workshop standard practice is largely a matter for the internal consideration of each manufacturing organization; nevertheless it can be only simplified by basing the originating design requirements on a common denominator of acceptability in all those countries to which it will ultimately be supplied.

4 OPERATIONAL AND SYSTEM-PLANNING SIMPLIFICATION

As indicated in Section 2, any telecommunications system should be based from its inception on its ultimate possible participation as one link in a world-wide chain.

Just as international organizations such as I.S.O and I.E.C provide for international standardization of engineering practices so the International Telecommunications Union covers operational and system-planning. Brief notes have appeared elsewhere[1] on the work of the I.T.U and its four constituent committees, with particular reference to the

adoption of the channelling techniques meeting C.C.I.T requirements for line and cable systems for the equivalent wide band radio links.

The recommendations, reports and resolutions issued as the result of successive Plenary Assemblies of the C.C.I.R cover agreed uniformity of practices in all aspects of international networks; without such agreement modern and international communications systems as we know them would have been impossible.

It is at once a paradox and a challenge that even in that field of applied science dedicated wholly to the international exchange of information, a large measure of initial chaos usually precedes the ultimate essential simplification.

Acknowledgements

The writer is indebted to Mr. G. Weston, Technical Director of the British Standards Institution, for checking the brief historical data concerning the growth of national and international Standards; also to Professor Geneve of the same Institution for making available notes from which these historical data were condensed.

References

[1] W. A. E. QUILTER: 'Radio Relay Systems and the C.C.I.F'. *Point to Point Telecommunications* 1, 1 (October 1956).

R. B. ARMSTRONG, born in Barbados in 1897, and educated at Harrison College, Barbados and the University of Durham. At the start of the first World War, he erected an emergency radio station for the Government of Barbados. He came to England and served in the Royal Naval Air Service until 1917, when he was shot down and taken prisoner of war.

He joined the Marconi organization in 1922, and in 1926 took charge of receiver development. He was a member of the first post-war American/Canadian technical fact finding mission in 1947, and he attended the C.C.I.T Conference in Brussels in 1948. He was appointed Manager of Marconi's Standardization Division in 1950, and is a member of various technical committees including the C.C.I.R and the British Standards Institution.

Collaboration in Development

THE INTRODUCTION of the 'Autoplex' Error Correcting Multiplex system by Marconi's is the outcome of a most successful collaboration between the General Post Office and the engineers of the Company.

The basic work on this system was initiated at the Post Office Research Station at Dollis Hill and experimental models were produced which amply demonstrated that with further design engineering a practicable system could be put into production. This system was known as Error Correcting Multiplex, otherwise ECM.

Parallel with this primary development Marconi's had been taking an increasing interest in this type of system and arising out of discussions with the G.P.O. it was agreed that all the information on the ECM system should be made available to industry so that a final engineering design could be initiated and thus lead to production of an all-British system. A team of Marconi engineers therefore commenced work in the early part of 1957 and with the continued assistance of the Dollis Hill engineers and the loan of a working model of the original ECM they were able to design a final equipment which is now known as Autoplex. This design work included the re-engineering of many features of the original experimental ECM models and the design of printed wiring for the complete equipment.

The development of this equipment is an excellent example showing how basic work carried out in Post Office laboratories can be taken over by industry and translated into production designs with the minimum of delay.

It is well known that the basic patents covering Automatic RQ Systems of this type are those by Van Duuren of the Dutch Posts and Telegraphs Department and Marconi's are licensed to design and produce these equipments using the Van Duuren patents.

* The article in our February issue 'Automatic Error Correction on HF Telegraph Circuits' by P. R. Keller has aroused wide interest and it was felt that a brief review of the development of this equipment in this country would be of interest. EDITOR.

The Analysis of Field Strength Records for Radio Link Assessment

M. W. GOUGH, M.A, A.M.I.E.E

The planning of microwave links usually necessitates a preliminary radio survey in the appropriate frequency band, because the propagation behaviour of radio paths cannot often be forecast with sufficient accuracy to predict reliably the performance of the projected communications system. This article reviews some of the recording and analytical techniques that may be applied to microwave surveys for FM multichannel links. Surveys, by the Marconi Company, have been operated virtually continuously in many parts of the world during the past 7 years, and have yielded many thousands of hours of signal strength recordings under a great variety of topographical and climatic conditions, from which much useful information has been extracted.

While primarily concerned with recording and analytical techniques, the discussion includes brief comments on a few noteworthy propagation effects exemplified in the accompanying charts.

1 INTRODUCTION

THE RECORDING AND ANALYTICAL TECHNIQUES to be described are primarily intended for assessing the performance, after preliminary survey, of projected high quality wide band radio systems which, while not necessarily requiring line of sight paths, nevertheless rely on orthodox modes of tropospheric propagation. Some of the processes are also well adapted to the investigation of propagation by tropospheric scatter. Broadly speaking, tropospheric scatter techniques are at present applicable to the frequency band 300-2 000 Mc/s, while wide band radio systems may exploit any part of the broad spectrum between 50 and 10 000 Mc/s. While many of the processes to be discussed have been evolved to suit the propagation characteristics of the latter frequency band, they are of course adaptable to other bands.

For short radio paths well within the visual range, the signal component travelling by the most direct propagation path dominates the relatively weak signals which may be simultaneously received by scattering or partial reflection from refractive index irregularities in elevated regions of the atmosphere.[1] Under these conditions the resultant signal is virtually fade-free unless periodic destructive interference by a strong ground-reflected signal occurs. As the path length is increased, with consequent weakening of the orthodox signal component, the secondary tropospheric components become relatively more important and begin to cause interference effects manifested as significant fades. Moreover the orthodox component itself becomes increasingly susceptible to changes in atmospheric refraction. Thus the variability of the resultant signal, both long-term and short-term, increases fairly rapidly with distance. Moreover the rapidity of fading tends to increase with frequency, as phase changes occurring between the various interfering components are themselves proportional to frequency.

When the range is extended somewhat beyond the horizon distance, propagation via random tropospheric irregularities usually over-rides the orthodox signal consistent with idealized '4/3 earth' propagation. This region marks the beginning of the domain of 'tropospheric scatter' techniques.[2]

Statistically, the received signal strength near and beyond the visual range can often be idealized (for short periods at least) as the resultant of numerous components having comparable amplitudes and random phase relationships. This leads to the well known Rayleigh distribution of signal levels, which is often approached in practice for short-term variations over paths of this type.[3] Over longer periods, when random weather changes significantly modify the atmospheric refractive index gradient above the path, distributions may approach a log-normal rather than a Rayleigh law. Over short paths, where one or two signal components are strongly dominant, other statistical idealizations are appropriate and these distributions are not to be expected. The comparison between observed statistical behaviour and that predicted by various idealizations[4] provides a valuable means of inferring what dominant propagation mechanism is operative.

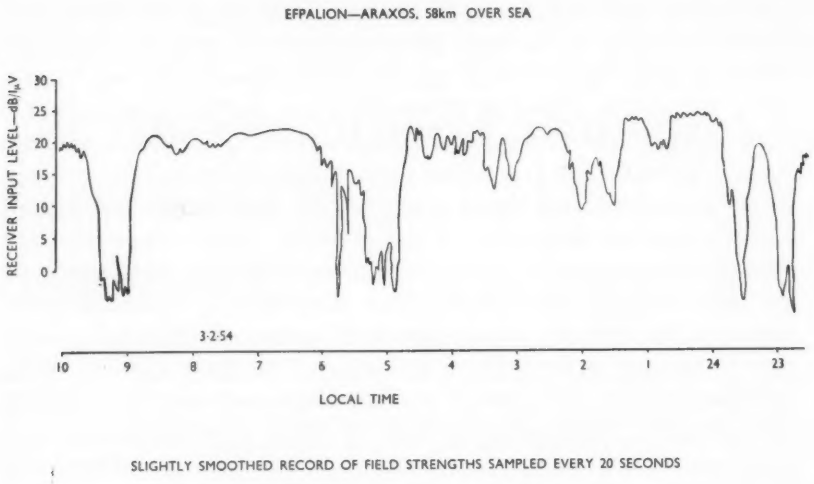


Fig. 1. Sample of over-sea record, Greece. 1 275 Mc/s

It is against this background that the following discussion on recording and analytical techniques must be viewed.

2 ELECTRO-MECHANICAL RECORDERS

Brief consideration will now be given to the salient factors governing the choice of electro-mechanical recorders associated with automatic signal strength measuring equipment, from which the requisite statistics of path performance are ultimately derived. From the purely engineering aspect, it is adequate that the recorder shall follow the signal variations sufficiently well to allow accurate measurement of the field strength exceeded for 99·9% of the period of test, this being the usually recognized percentage of the time for which the specified circuit quality must be maintained. Two types of recorder are in common use. The first records signal variations continuously, and the second samples these variations at regular short intervals. The record appears on a moving paper chart, in the first instance as a continuous fluctuating line and in

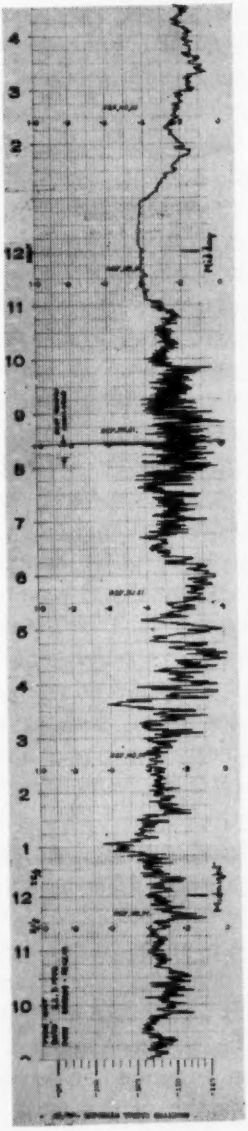


Fig.2. Sample of record. Monte Nerone—Monte Peglia, N. Italy. 2000 Mc/s

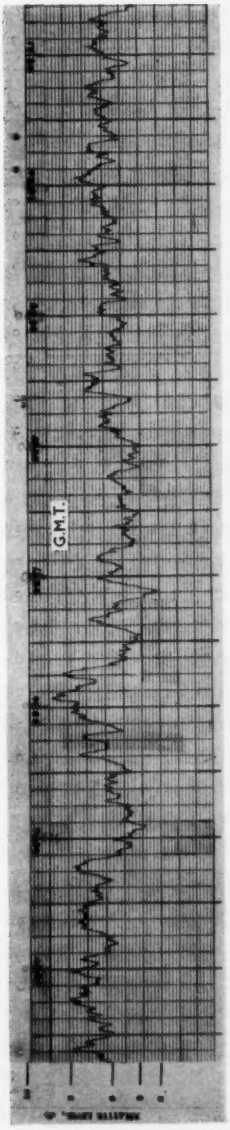


Fig.3. Sample of fast record. Monte Nerone—Monte Peglia, N. Italy. 2000 Mc/s

the second instance as a chain of closely spaced dots. The latter system has the advantage that the time between signal strength measurements, which may be one or two minutes, can be usefully occupied in automatic calibration of the receiver or for other monitoring purposes, or for recording another transmission if desired. There is the further advantage that the recorder movement is unimpeded by friction with the paper chart. The inevitable loss of information due to sampling is seldom statistically important below about 500 Mc/s, if sampling intervals of one or two minutes are employed. At higher frequencies, where signal strength fluctuations are likely to become progressively more rapid, a faster sampling rate is advisable, particularly where deep fading is encountered, so that the record shall indicate accurately the signal strength exceeded for the required high percentage of the time. A general-purpose recorder in common use will sample signal strength at 20-second intervals if none of its time is devoted to monitoring the equipment. This gives an adequate statistical representation of propagation variations up to frequencies of 2 000 Mc/s at least (Fig.1).

The continuously-writing type of recorder can produce, subject to the limits of its electro-mechanical response, the fine detail sometimes required in research on propagation mechanisms, such as, for example, diversity reception. For such work, instruments responding respectively to maximum fluctuation rates of 1, 15 and 70 cps are in common use. With the exception of the slowest-acting instrument, the recorders are fitted with two styli which can be independently driven over a common paper chart of adjustable speed. Thus one stylus can be used for marking time intervals against a signal strength record made by the other. Alternatively the styli can record separate signal sources simultaneously, which is a facility essential in the investigation of diversity systems.

The single-pen 1 cps recorder is useful up to about 4 000 Mc/s, if all that is required is verification that the path under test will give the requisite signal-to-noise ratio for a specified percentage of the time. Fig.2 shows part of a 2 000 Mc/s record made over a land path in Italy by this slow acting but robust type of instrument. Fig.3 is an example of a 2 000 Mc/s record made by the 15 cps instrument, showing fine detail during a period of rapid fading over the same path.

3 PROCESSES OF SIGNAL RECORD ANALYSIS

Turning now to the analysis of conventional field strength records, the techniques outlined below aim at the concise presentation of information needed to assess the performance of radio links under various specific conditions. There are many statistical processes, applicable as much to research on wave propagation mechanisms as to the engineering of specified links, which cannot be described here. Among such investigations, directed towards general furtherance of the communications art, may be mentioned the correlation of signal strength with the gradient of atmospheric refractive index,[5] and assessment of the effectiveness of diversity systems. C.C.I.R have made broad recommendations for the presentation of data connected with tropospheric propagation studies.[6,7] They emphasize that, because of rapid progress in this field, it is inadvisable to be over-specific on methods of presentation. Thus while the methods outlined hereafter embody C.C.I.R's basic statistical recommendations, they include further processes which have been found useful. The literature shows that the same statistical information can be presented in many superficially different ways,[3,8,9,10]

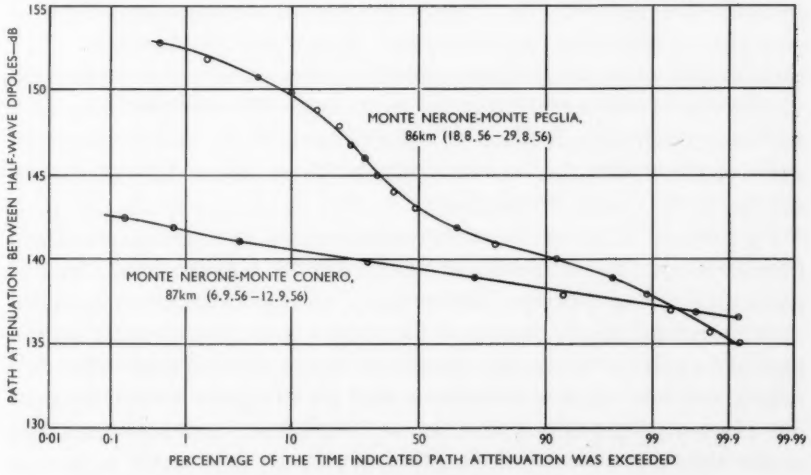


Fig.4. Cumulative distributions of path attenuations, 2 000 Mc/s, N. Italy

and often the mode of presentation is a matter of personal preference rather than of intrinsic merit. Therefore the following procedures should not be considered as exhaustive, but as a guide to basic methods. It is certain that the rapid evolution of very wide band radio links will stimulate the development of new analytical techniques.

In planning a radio link, the basic requirement is knowledge of the signal-to-noise ratio, for example in the noisiest voice channel of a multiplex system, which is likely to be exceeded for various percentages of the time. Knowing the instrumental characteristics of the proposed installation, this information can be derived from analysis of survey recordings in the appropriate frequency band, examples of which have already been given in Figs.1 and 2. The measured percentages of the total recording time for which various signal strengths were exceeded are best plotted on arithmetic probability paper, using a scale of signal strengths expressed in decibels referred to a convenient datum (e.g. 1 microvolt or 1 watt) to facilitate conversion, when required, to a scale of path attenuations or signal-to-noise ratios in a particular system. Because this type of chart has a percentage scale shaped according to a Gaussian or 'normal' law of errors, this method of plotting gives a straight line on the chart for a log-normal distribution of signal strengths, which may be approached in certain circumstances. Fig.4 shows cumulative distributions plotted in this way from recordings on 2 000 Mc/s of two overland paths in N. Italy. The divergent slopes of the respective curves indicate a large difference in the fading characteristics of the two paths, one of which (with the lesser fading) closely follows a log-normal distribution.

Fig.5 shows a set of cumulative distributions pertaining to a single overwater path tested under various conditions. It is seen that, for this particular optical path in Greece, signal strength variations recorded simultaneously on 175 Mc/s and 1 275 Mc/s were much greater on the higher frequency, while the lower frequency showed somewhat less fading with vertical than with horizontal polarization. These effects are due to varying degrees of destructive interference between direct and water reflected waves periodically engendered by changes in atmospheric refraction. In the case of the lower frequency the resulting phase

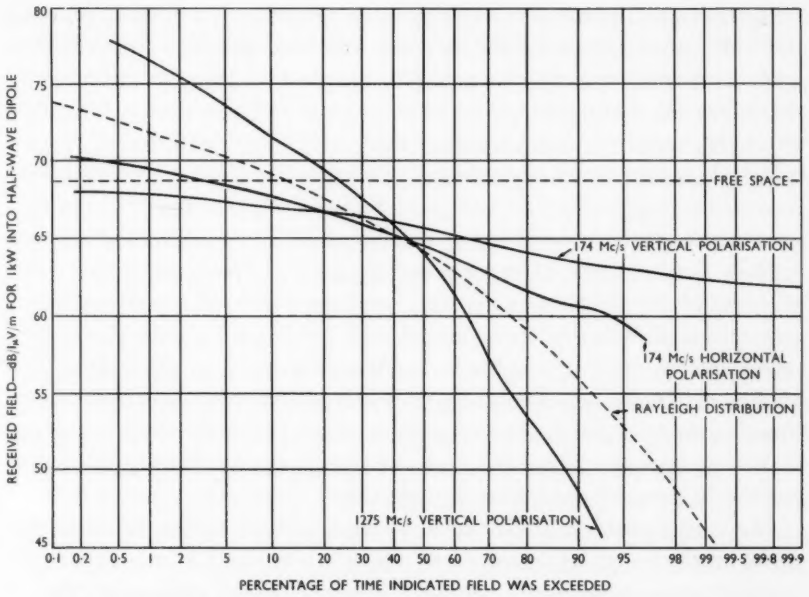


Fig.5. Effect of polarization and frequency on behaviour of over-sea 90 km path, Greece

shift between the two waves is sufficiently restricted to exclude the possibility of complete phase opposition, thus avoiding the deep fades which would otherwise result from mutual cancellation between opposing waves of nearly equal amplitude. However on 1 275 Mc/s, the proportionately increased phase shift with frequency allows ample scope, within the usual variations in atmospheric refraction, for several states of mutual cancellation. Moreover whichever polarization is used at this frequency, the reflection coefficient at shallow angles to the sea surface is very close to 1, implying deep fades during periods of phase opposition. The effect is exemplified by the 1 275 Mc/s distribution on Fig.5, which indicates worse fading than is compatible with the Rayleigh distribution shown by the superimposed broken curve. This is to be expected on theoretical grounds if the received signal can be idealized as the resultant of two nearly equal components in random phase.

In contradistinction to 1 275 Mc/s, the use of vertical polarization in the VHF band offers a significant reduction from unity in the reflection coefficient of the sea at shallow angles. This is due to the fact that, while the reflection coefficient for horizontal polarization is nearly unity for all angles, that for vertical polarization falls to a low value at the so-called pseudo-Brewster angle. In the VHF band this angle approximates to those occurring in practice, but as the frequency is increased the pseudo-Brewster angle becomes greater, and therefore little relative advantage accrues from the use of vertical polarization at frequencies above approximately 1 000 Mc/s. In the VHF band the lower reflection coefficient gives reduced fading by comparison with horizontal polarization, as is confirmed by the two 174 Mc/s distributions on Fig.5. This advantage applies of course only to fading of the type discussed, which is sometimes termed *k*-fading. The topography of the majority of optical paths is such as to make *k*-fading a rare occurrence in the VHF band but increasingly prevalent at higher frequencies.

The statistical significance of any cumulative distribution curve depends on the length of record from which it is derived. However a chart derived from a long record must be interpreted with circumspection if it is not to mislead, as it conceals any periodic trends operating during the test period. These, if well marked, require individual treatment. A typical case is a cumulative distribution based on a test period of a week or more over a path subject to violent diurnal variations, such as occur in some tropical and desert regions. In this case separate cumulative distributions are necessary for selected portions of the 24 hours (e.g. between 1000 and 1800 hours local time when signals are often low and steady, and during the remainder of the 24 hours when signal strengths are likely to be very high and variable). It is also useful in these circumstances to compute a cumulative distribution curve restricted to business hours, for example 0700-1500 hours in the tropics. For similar reasons, when continuous recordings are available for more than 2-3 months, the well-known seasonal trend in signal strength may necessitate the preparation of a number of cumulative distribution curves covering for example successive one-monthly periods. Further, to verify that a requirement for a specified performance during the busiest hour of the day

can be met, it is sometimes necessary to plot, for each day of test, a 'within-the-hour' distribution curve for that particular hour.[3]

From the foregoing types of cumulative distribution the fading range applicable to a specified test period can be quickly read off. The fading range is variously defined in the literature as the difference (in dB) between the levels exceeded for the following paired percentages of the time:

90% and 10%,
99% and 50%,
99·9% and 50%

In the opinion of the author the median (50%) level is the preferred fading datum because it often approximates to the theoretical level based on '4/3 earth' refraction. It is this theoretical basis which is often used in the selection of provisional radio paths for confirmatory survey.

When long and rapidly fluctuating records require analysis, a cumulative distribution of hourly mean (or median) levels is sometimes a useful alternative to the distributions of instantaneous levels already described. Compared with these, a distribution of hourly mean levels involves some loss of information, but it saves much analytical labour when the level is constantly fluctuating, because the hourly mean levels can be estimated sufficiently well by eye, and subsequently plotted in cumulative form. For a record of adequate length, the distribution of hourly mean levels usually differs little from that of the instantaneous levels for low percentages of the time, but for the higher percentages (e.g. above 70%) it is likely that the hourly mean level will significantly exceed the instantaneous level.

The hourly mean signal level is virtually free from the statistical influence of fluctuations caused by scattering and partial reflections from tropospheric irregularities, and moreover for paths of simple profile it is related in a calculable way to the effective earth radius factor, k, operative during the hour in question. In this way a cumulative distribution of hourly mean signal levels can be simply converted to a distribution of k values[11], which is useful in predicting the general behaviour of radio paths (not necessarily in the test frequency band) which may sub-

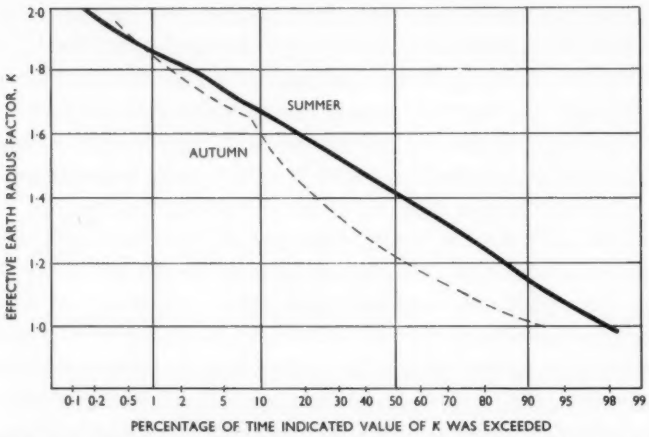


Fig.6. Cumulative distributions of effective earth radius factor 320 km over-sea path between Cyprus and Israel (77 Mc/s)

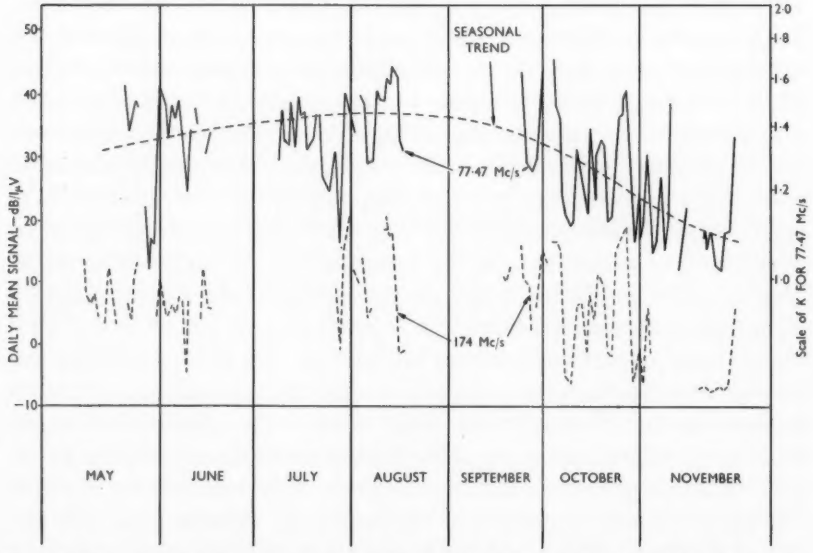


Fig.7. Daily mean signal strength on two frequencies, Cyprus—Israel. 320 km. Over sea. Transmitted powers: 77 Mc/s, 200 watts; 174 Mc/s, 3 watts

sequently be planned in the same region. Fig.6 shows two cumulative distribution curves of k, derived in this way from prolonged measurements on 77 Mc/s over a 320 km non-optical sea path between Cyprus and Israel. The 'summer' curve, covering May to mid-August, and the 'autumn' curve covering mid-September to the end of November, show respective median k values of 1·4 and 1·2. The autumnal decrease in the median k value causes a reduction in the mean signal strength of about 10 dB relative to the summer period for the frequency in question.

Cumulative distribution curves inevitably have limited value when based on short term recordings. When a chain of radio links has to be surveyed, economic considerations usually limit the recording period to about one week per path. while due to weather and seasonal changes it is apparent that recordings over a different week may yield a different result. Nevertheless this disadvantage is overcome to a great

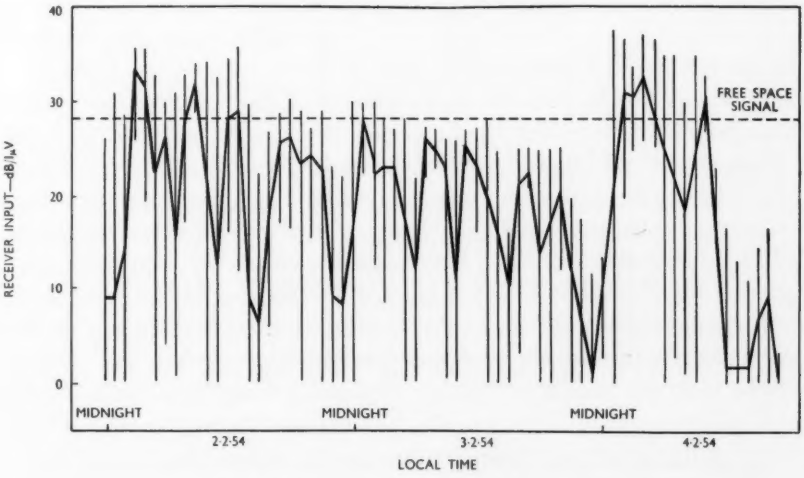


Fig.8. Representation of hourly fading ranges

The extent of the vertical bars shows the maximum and minimum levels recorded during any specified hour. The interconnecting lines show the hourly mean levels. Araxos–Efpalion (Greece) 58 km over sea. Frequency, 1 275 Mc/s.

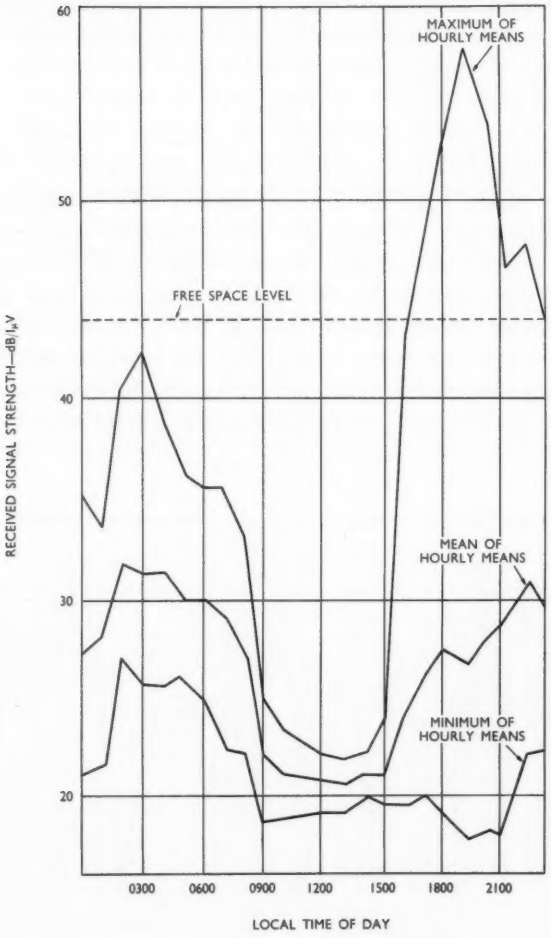


Fig.9. Representation of recurrent diurnal variations over a number of days, method (a)

Hourly mean levels are tabulated for a specific hour of each day's record to derive the maximum, minimum and mean values (relevant to the whole test period) for that particular hour. The process is repeated for each hour of the day and the diurnal variations of the three quantities are plotted as illustrated above. 50km overland path in Kuwait. (31.10.56—10.11.56). Frequency, 180 Mc/s.

extent when successive recordings of this kind, reinforced by weather observations, are continued over a large region for a year or more. In these circumstances it is possible to construct a useful picture of the radio-meteorological peculiarities of the area, from which the statistical behaviour of projected radio links can be assessed.

When recording over a single path can be maintained over a period of months, the daily mean signal strength can be usefully plotted in order to reflect weather and seasonal changes. Fig.7 shows daily mean signal strengths on 77 and 174Mc/s recorded intermittently but often simultaneously for 7 months over the Cyprus-Israel path already referred to. The signal is itself well correlated with the average effective earth radius factor for the day in question, the relevant values of which are indicated on a scale of k to the right of the chart. The quantity k is also simply related to the gradient of atmospheric refractive index (see Appendix). Fig.7 shows large fluctuations in daily mean signal strength (and therefore in k) attributable to weather changes, which nevertheless fail to obscure a declining trend in signal strength during the autumn, as indicated by the dotted line.

Figs.8, 9 and 10 show three methods of concisely representing signal strength variations. The commonly employed method of Fig.8 has the virtue of showing at a glance the depth of fading, the incidence of diurnal variations (when present) and slower trends due, for example, to weather changes. Figs.9 and 10 illustrate alternative ways of representing recurrent diurnal variations recorded for a number of successive days. In all three processes, median values (i.e. those exceeded for 50% of the time) can be used instead of mean values if desired. While there is seldom any great numerical difference between the two quantities, the median level has the practical advantage of being determinable even when the signal is lost in noise for a certain fraction of the time which must not, of course, exceed 50%.

While Fig.9 impressively illustrates the wide nocturnal variations in hourly mean levels experienced during a 21-day test, the process of Fig.10 (which refers to a neighbouring path subject to similar climatic influences), gives a better representation of path performance. This is because the standard deviation (see Appendix) of the hourly mean levels

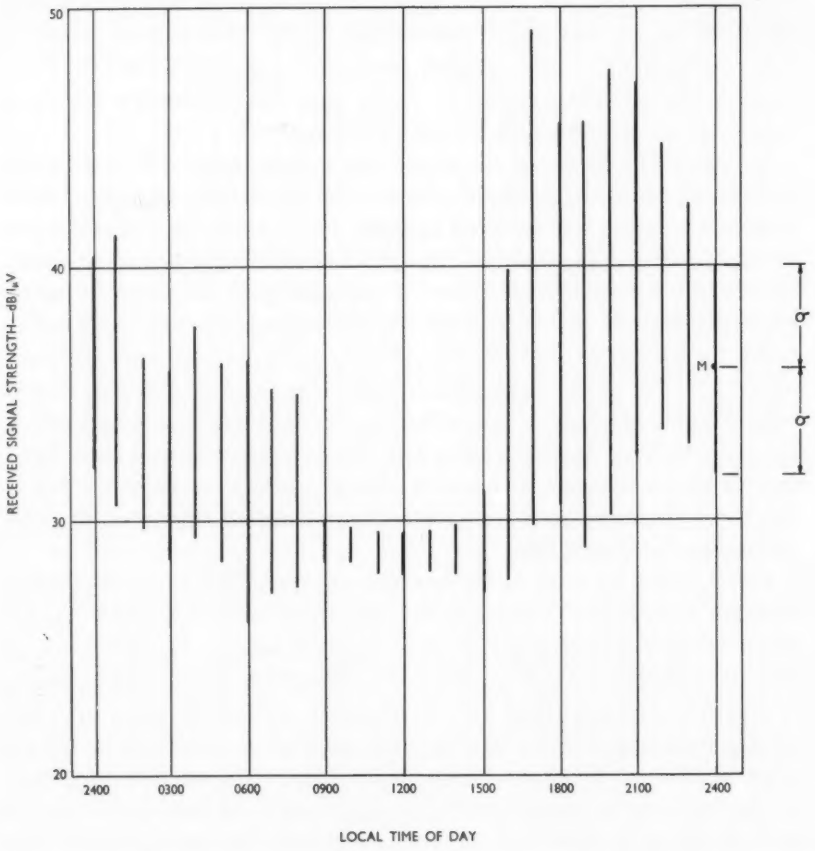


Fig.10. Representation of recurrent diurnal variations over a number of days, method (b)

Hourly mean levels are tabulated for a specific hour of each day's record. The mean of the tabulated values is computed, together with their standard deviation σ expressed in dB.

Vertical bars are erected at hourly intervals above the time scale as illustrated, so as to extend an amount σ (dB) above and below the point M representing the mean of the hourly mean levels. The chart is completed by repeating the process for each hour of the day. Kuwait Town—Ahmadi, (Kuwait) 31 km over land. (2.10.56—16.10.56). Frequency, 180 Mc/s.

on which Fig.10 is based, avoids the attachment of undue weight to the maximum and minimum values (Fig.9) which, from statistical considerations, are likely to occur only occasionally.

Propagation phenomena illustrated by Figs.8, 9 and 10 merit brief comment. Fig.8 refers to a 1 275 Mc/s optical sea path in Greece, which shows random fading due to recurrent destructive interference by sea reflections, the mechanism of which has already been discussed. Figs.9 and 10 are derived from 180 Mc/s measurements in Kuwait. They illustrate the remarkable steadiness over respectively 21 and 13 successive days, of the signal level between 0900 and 1500 hours, as opposed to its great variability outside these hours. This transition is due to the regular nightly formation of an intensely refracting layer in the first few hundred feet of the atmosphere. The general effect of this is greatly to increase the signal strength near the ground during this period, unfortunately often interspersed with deep fades. The formation of the superrefracting surface layer responsible for the effect is promoted by the cooling of the heated land when the night sky is clear. Very similar effects have been measured in Nigeria and Ghana. Fig.11 shows typical hourly fading range charts from the latter, together with an example from Malaya where the effect is invariably far less pronounced. Analogous influences have been observed in the Arizona desert, where several simultaneous VHF and UHF transmissions have exhibited diurnal variations consistent with atmospheric conditions derived from low-level meteorological soundings.[5]

The degree of fading over a specific radio link can vary greatly with frequency. When transmissions on two or more frequencies have been recorded simultaneously over a common path, the relation between fading and frequency can be strikingly shown by plotting against frequency the percentages of the time that specified depths of fading below the median signal level were exceeded. Fig.12 shows such a chart for a mainly sea path in E. Africa, based on 3 simultaneously recorded transmissions on respectively 77, 169 and 1 275 Mc/s. The chart enables an estimate to be made within the frequency band 70-2 000 Mc/s of the approximate percentages of the time that fades of, for example, 3, 5, 7 and 10 dB below the median level are likely to be exceeded for the path in

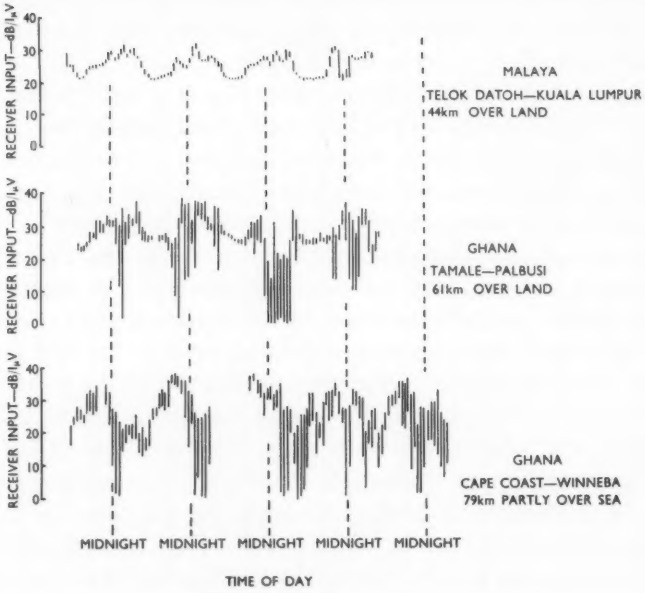


Fig.11. Diurnal variations as shown by hourly ranges

question. Most charts of this description show a tendency for the percentage of the time occupied by fades to increase with frequency. This fact is associated, among other influences[10], with the shifting phase of ground and water reflections already mentioned.

4 FUTURE TRENDS

With the ever-increasing number of voice channels carried by microwave links, increasing attention will have to be devoted to countering effects which have tended hitherto to be dismissed as of secondary importance. Among these may be mentioned the propagation of multipath signals by reflection, scattering and re-radiation from such objects as buildings, hills, power lines, etc. flanking the radio path. Although these indirect signals are relatively very weak on a properly engineered link. they may in some circumstances significantly increase inter-channel

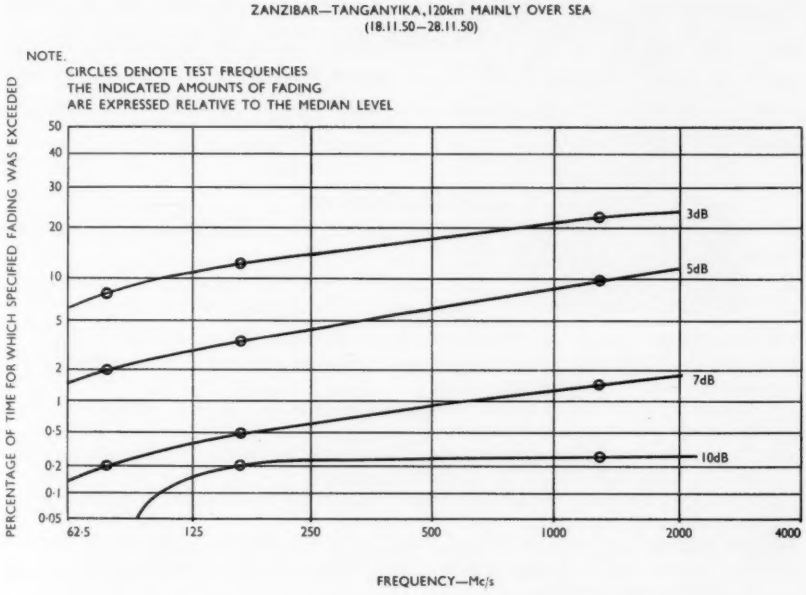


Fig.12. Influence of frequency on fading behaviour, E. Africa

cross-talk in systems employing large numbers of channels. Another factor which may eventually place limitations on very wide band FM and AM systems is the presence of random small amplitude and phase modulations imposed by the progagation medium itself, which would introduce extra noise into the system, and possibly inter-channel cross-talk as well. In that event the significant signal fluctuation rates would far exceed these catered for by conventional electro-mechanical recorders. Investigation of this effect would require a CW transmission monitored over a test path by a wide-band receiver and linear detector. Any amplitude modulation introduced by the progagation path would, after detection, be passed through a video amplifier for examination in various ways. For example, the peak amplitude or the rate of variation of the spurious modulation could be recorded over a period, or its frequency spectrum analysed. Alternatively, the substitution of a FM limiter and

discriminator in place of the detector would reveal any frequency modulation introduced by the propagation path. Such investigations would enable an estimate to be made of the atmospheric and instrumental conditions under which significant deterioration of system performance could be expected.

Acknowledgements

Acknowledgement is made to the Institution of Electrical Engineers and the Kuwait Oil Company for material incorporated.

References

1 E. C. S. MEGAW: 'Waves and Fluctuations'. *Proc. Instn. Elect. Engrs.* 100, Part III (1953).
2 M. TELFORD: 'Communications Potentialities of Tropospheric Scatter'. *Point to Point Telecommunications* 1, 2 (February 1957).
3 H. B. JANES: 'An Analysis of Within-the-Hour Fading in 100 to 1000 Mc Transmissions'. *J. of Res. of the Nat. Bureau of Standards* 54, 231 (1955).
4 M. SLACK: 'The Probability Distributions of Sinusoidal Oscillations Combined in Random Phase. *J. Instn. Elect. Engrs.* 93, 76, Part III (1946).
5 J. P. DAY, L. G. TROLESE: 'Propagation of Short Radio Waves over Desert Terrain' *Proc. Inst. Radio Engrs.* 38, 165 (1950).
6 C.C.I.R London, 1953: Documents of the VIIth Plenary Assembly. Question No. 85 (V).
7 C.C.I.R Warsaw, 1956: Documents of the VIIIth Plenary Assembly. Recommendation No. 170 and attached Annexes.
8 G. S. WICKIZER, A. M. BRAATEN: 'Propagation Studies on 45·1, 474 and 2800 Mc/s, within and beyond the Horizon'. *Proc. Inst. Radio Engrs.* 35, 670 (1947).
9 J. Z. MILLAR, L. A. BYAM: 'A Microwave Propagation Test'. *Proc. Inst. Radio Engrs.* 38, 619 (1950).
10 R. L. KAYLOR: 'A Statistical Study of Selective Fading of Super-High Frequency Radio Signals'. *Bell System Tech. J.* 32, 1187, (1953).
11 M. W. GOUGH: 'Some Features of VHF Tropospheric Propagation'. *Proc. Instn. Elect. Engrs.* 102, 43, Part B (1955).

Appendix

THE STANDARD DEVIATION of a number of measurements is the root mean square value of their respective deviations from their mean. Thus if n measurements differ from their mean value by respective amounts d_1, d_2, d_3, d_4, . . . d_n, their STANDARD DEVIATION is $\sqrt{\dfrac{d_1^2+d_2^2+d_3^2+d_4^2+\ \ldots\ d_n^2}{n}}$

Further, if the distribution of the measurements is statistically normal (Gaussian), the STANDARD DEVIATION of the measurements is the difference between the value exceeded by 50% of the measurements and that exceeded by 84·1% of the measurements.

The EFFECTIVE EARTH RADIUS FACTOR, k, is given by

$$\frac{1}{1+R\,dn/dh}$$

where R is the earth's radius (metres) and dn/dh is the REFRACTIVE INDEX GRADIENT. The latter has a negative value, implying that k is usually > 1.

M. W. GOUGH, born at Redhill, Surrey, in 1915 and was educated at Sutton Valence School, Kent. Obtained an Honours degree in Mechanical Sciences at Cambridge in 1937. He joined the Marconi Company in that year and from 1938 to 1940 was engaged in the development of broadcast studio equipment. During the war he was seconded to the Air Ministry with the 'Eckersley Group'. After the war he specialized on the propagation problems of very short wave radio links.

His work in the field of radio wave propagation is well known and he has for many years carried out analyses of surveys from all over the world.

Designed by London Typographical Designers Limited. This journal is set in 8 pt and 12 pt Linotype Pilgrim and is printed in Great Britain on Bowater's Lithocote SM2 by The Shenval Press, London, Hertford and Harlow.

A.T.E. + MARCONI

Combined Operations

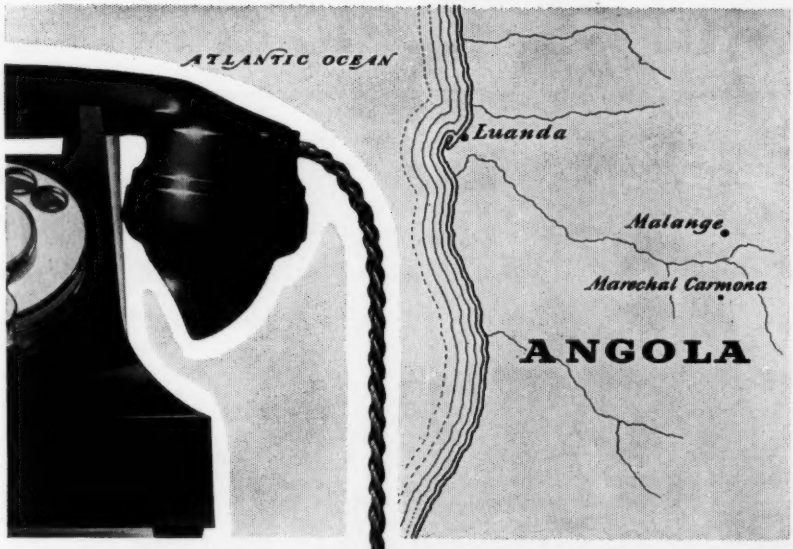
The complexity of modern radio-multichannel systems involving hundreds of telephone channels has brought about a collaboration between the two leading specialist organizations in the field—Marconi's in radio, and A.T.E. in carrier transmission.

This completely unified approach to development, systems planning, supply, installation, maintenance of equipment and training of personnel covers radio-multichannel systems in the V.H.F., U.H.F. and S.H.F. frequency bands all over the world.

Full information may be obtained from either:
MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND.

or AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2

Radio Telecommunications Network for Angola



The Angolan Postal and Telegraph Authorities have placed an order with Automática Eléctrica Portuguesa, S.A.R.L. for equipment to be manufactured and installed by Marconi's Wireless Telegraph Co. Ltd. and Automatic Telephone & Electric Co. Ltd. for a multi-channel radio telecommunications system linking the towns of Luanda, Malange and Marechal Carmona in Portuguese West Africa. The total distance is 600 Km. The radio equipment comprising 12 terminals and 16 repeaters is being supplied by Marconi's and A. T. & E. Co. Ltd are supplying the carrier telephone equipment. This, the first multi-channel radio system in Angola is the first stage in the implementation of a much larger scheme.

AEP

AUTOMATICA ELECTRICA PORTUGUESA
(S.A.R.L.)
AV. Antonio Augusto de Aguiar 19-3° E
Apartado 20/60 LISBOA

ATM

AUTOMATIC TELEPHONE & ELECTRIC COMPANY LIMITED
Strowger House, Arundel Street, London, W.C.2

Marconi

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED
Marconi House, Chelmsford, England

AT14761

TROPOSPHERIC SCATTER

Tropospheric Scatter phenomena were first observed by Guglielmo Marconi in 1932 and today Marconi's offer completely engineered tropospheric scatter systems in the frequency range 700—1000 Mc/s.

10 kW UHF Tropospheric Scatter Transmitter Type HS. 313 with middle bay open showing 10 kW Klystron

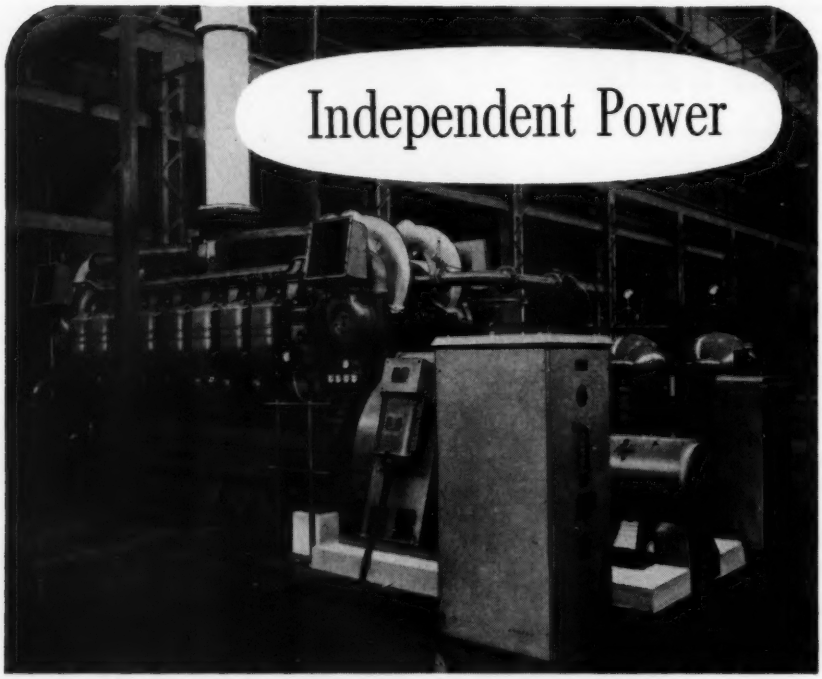
LC21

SYSTEMS

- The fully proved Marconi transmitters range in power from 500 watts to 10 kw.
- Double or quadruple diversity receivers can be used. The normal arrangement is for a quadruple diversity receiver to be associated with two transmitters carrying the same modulation, operating on two slightly different frequencies.
- The standard aerial system comprises a 30′ dish common to transmitter and receiver which is mounted on a steel tripod. 60′ dishes are available where the increased gain justifies the additional cost.

MARCONI *COMPLETE COMMUNICATION SYSTEMS*

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND



for signals stations

An 'ENGLISH ELECTRIC' 16SV 1,000 kW diesel alternator set of the type used for signals installations.
Continuity of services is ensured by automatic starting.
The field suppression cubicle and automatic starting panel can be seen in the right foreground.

'ENGLISH ELECTRIC'

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2
Diesel Engine Division, Brownsover Hall, Rugby. Telephone: Rugby 3391
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON
DE.E0A8

A NEW WORD IN COMMUNICATIONS

AUTOPLEX

Transmission over high frequency and VHF ionospheric scatter telegraph circuits of direct teleprinter traffic on a telex system demands substantially error-free transmission characteristics. Under these conditions, and also for data transmission circuits, the possibility of repetition often does not exist.

The alternative to greatly increased transmission power is the use of an error detection and correction arrangement.

The Marconi Autoplex equipment which is now in production has been designed to carry out the detection and subsequent correction of errors automatically. The equipment, which can be applied to existing HF telegraph circuits, provides 2 channels in time division multiplex for 100 baud circuits, and two equipments can be combined to give 4 channels where 200 baud circuits are available.

MARCONI AUTOPLEX

AUTOMATIC ERROR CORRECTING EQUIPMENT

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND

Reduce 'Outage' time on your teleprinter circuits – *with the T.D.M.S. 5B and 6B*

ATE Telegraph Distortion Measuring Equipment can be used to monitor a radio or line teleprinter circuit without interrupting traffic. It is compact, portable and versatile in its many functions. The various forms of distortion arising in synchronous or start-stop transmission may be identified or measured on a C.R.T. screen. Signal speeds can be determined directly. Test signals can be sent with any desired percentage of distortion up to 50% and at most normal operational speeds between 40-160 bauds. High speed relays may be tested for neutrality, transit times and contact bounce by visual indication of their behaviour on the C.R.T. screen. The equipment is in two units TDMS 5B and TDMS 6B. Either may be used independently. Together they cover a complete range of tests.

T.D.M.S. 5B

Sends an automatic test message, or characters, or reversals at any speed between 40-80, 140-160 bauds with or without distortion. The C.R.T. has a circular time base for distortion measurements on synchronous signals only. Weight 38 lb. (17.1 kg.)

T.D.M.S. 6B

For distortion measurements on working circuits without interrupting service. Each element of a start-stop signal appears separately on a spiral time base display. Speed 40-80, 140-160 bauds. Weight 34 lb. (15.3 kg.)

You are invited to apply for a descriptive brochure

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

STROWGER HOUSE · ARUNDEL STREET · LONDON · WC2

Tele : TEMple Bar 9262 Strowger Works · Liverpool 7

AT 14771

BIC Construction Company design, supply and install all types of Radio Masts and Towers for Telecommunication Schemes anywhere in the World.

Current work for Marconi's includes projects in Iran and Ecuador.

MASTS & TOWERS

for every type of Telecommunication System

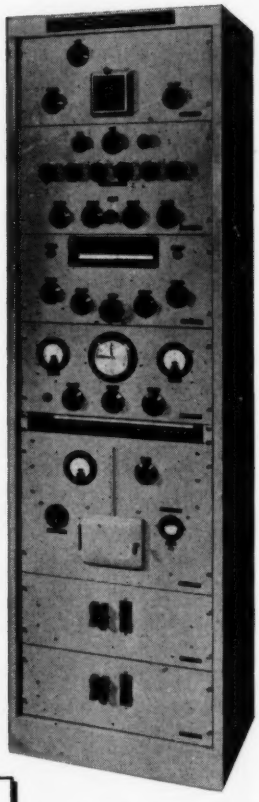
BRITISH INSULATED CALLENDER'S CONSTRUCTION CO. LTD.

30 LEICESTER SQUARE, LONDON, W.C.2.

Member of the BICC *Group*

Precision Frequency Measuring Equipment

Type TME 2



FREQUENCY MEASURING EQUIPMENT Type TME 2 comprises a complete and self-contained installation for the direct determination of frequency with a very high order of accuracy. This equipment is suitable for large transmitter stations operating primary services, and for central monitor stations.

A crystal-controlled master oscillator drives a chain of divide-by-ten multivibrators, a synchronous clock, and a stroboscope system; the signal under test is heterodyned with an oscillator locked to the multiplier chain, and the unknown frequency is read directly from the decade indicators and the stroboscope. The synchronous clock enables the accuracy and stability of the crystal to be checked against time signals.

ABRIDGED SPECIFICATION

FREQUENCY RANGE: 1 kc/s to 30 Mc/s with continuous direct decade indication to 1 c/s.

ACCURACY: ± 1 part in 10^8.

STROBOSCOPE: Direct-reading range of 100 c/s readable to 0.01 c/s.

MARCONI INSTRUMENTS

AM & FM SIGNAL GENERATORS AUDIO & VIDEO OSCILLATORS VALVE VOLTMETERS · POWER METERS · Q METERS · BRIDGES WAVE ANALYSERS · FREQUENCY STANDARDS · WAVEMETERS TELEVISION AND RADAR TEST EQUIPMENT · AND SPECIAL TYPES FOR THE ARMED FORCES

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTFORDSHIRE

Telephone: St. Albans 56161

London and the South: Marconi House, Strand, London, W.C.2. Tel: COVent Garden 1234

Midlands: Marconi House, 24 The Parade, Leamington Spa. Tel: 1408

North: 23/25 Station Square, Harrogate. Tel: 67455

WORLD-WIDE REPRESENTATION TC 97